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# SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to The Editor of Science, Garrison-on-Hudson, N. Y.

## MEANS FOR THE SCIENTIFIC DEVELOPMENT OF MATHEMATICS TEACHERS<sup>1</sup>

THE war just and justly closing has many lessons for teachers. One of these is that those who are best prepared intellectually and have a deep interest in their subject will win in the end. Pedagogy like militarism trains directly for the object, but knowledge of the subject like the development of the general resources of a country gives real power and endurance. I fear our schools, especially our universities, have lately tended towards the former type of training for teachers and it is hoped that one of the lessons of this war is that there is danger in this direction. Pedagogy, as far as it enables the teacher to make students study what they do not want to study, is the militarism of the teaching profession.

Among the other lessons which this war has taught us as teachers of mathematics is not to lose our confidence in the great usefulness of our subject. If any of us were discouraged during recent years by those who talked thoughtlessly but effectively about the uselessness of algebra and geometry we doubtless have largely recovered from this discouragement. The courses for the Students' Army Training Corps, as well as those given under the auspices of the Y. M. C. A. at the various naval stations, exhibit the extensive mathematical needs of those who aim to render the most efficient service under the most trying circumstances. Our new merchant marine will continue to make large demands for men with considerable mathematical training and will thus tend to emphasize the practical usefulness of our subject.

<sup>1</sup>Prepared for the meeting of the Missouri Mathematics Teachers, which was to be held on November 8, 1918, but was postponed on account of the influenza epidemic.

It is still more important to note the value of mathematical training from the point of view of good citizenship. American lower schools devote much more time to mathematics and other sciences than the corresponding schools of Germany and the "German primary and secondary education is more intensely classical and literary than is British."<sup>2</sup> Mathematics has for centuries been most highly appreciated in France and it has been most thoroughly mastered in the French schools. The account which the French soldiers have given of themselves during the world war is therefore the more inspiring to us as teachers of this wonderful subject.

The mathematics teachers are the mothers of mathematical progress, while the investigators are its fathers. Our teachers' organizations are thus a kind of mothers' clubs where we are inclined to discuss chiefly matters relating to the interests of those committed to our care. The highest devotion implies however, more than self sacrifice. It implies also thoughtful and arduous preparation. In fact, such preparation tends to make our tasks much easier and the things that we can do easily are usually done most efficiently. Hard intellectual work should be done only privately. All such public service should be easy as a result of thorough preparation.

My principal object is to inspire some of you to form a new resolution to strive to grow more rapidly along mathematical lines. The scientific development of teachers is not only a state and national question of paramount importance but it is also of international significance. At the outbreak of the world war its instigator Germany offered several prizes for essays relating to the best ways of using the facilities already at hand and of providing additional facilities for advancing the interests of those engaged in teaching.<sup>3</sup>

The glorious intellectual advances made by American secondary teachers during the last

two or three decades is reflected in the rapid transformations of our universities in favor of teachers. These transformations have been so rapid and extensive as to give us little time to reflect upon their bearing and may have advanced already beyond the danger point.

The summer sessions and the summer quarters of our universities have grown rapidly in importance and influence. The universities are enlisting more and more their best talent for teachers during the summer terms instead of allowing their less progressive members to utilize them to increase their salaries.

Secondary teachers can not be urged too strongly to attend these summer sessions whenever they can do so without endangering their health. Teachers of mathematics in particular should aim to take at least one or two courses in the department of pure mathematics, and should not devote themselves too closely to the study of the methods or the history of teaching. The main element of interest about mathematics is the subject itself and the more advanced subjects throw the clearest light on the more elementary parts. In fact, these advanced subjects are only the elementary subjects grown to manhood and we understand the boy better after we have watched him develop into a man. Methods, on the contrary, are simply the outer garments of our subject and no amount of dress will make a skeleton attractive.

A child once watched a robin bearing a worm to its nest filled with little ones stretching out their necks and widely opened mouths in eager expectancy. The mother robin gave little heed to these gaping mouths, and, after resting a few seconds on the edge of her nest, swallowed the worm herself. The child was exasperated and called the mother robin a horrid old thing, but the father of the child directed attention to the fact that if the mother robin would not preserve her strength the helpless little robins would soon have no one to provide for them.

This simple illustration may serve to emphasize the need of looking after our own intellectual sustenance and growth. The help

<sup>2</sup> W. J. Pope, "Science and the Nation," 1917, p. 3.

<sup>3</sup> *Zeitschrift für naturwissenschaftlichen Unterricht*, Vol. 45, 1914, p. 521.

we can render our students is a function of many variables but among these variables our own knowledge of the subject which we try to teach is doubtless the most significant. Our enthusiasm for the subject is likely to grow with this knowledge and is another important variable upon which our success will depend. It should also be noted that an enthusiasm which is expressed only in words is not likely to reach the student's heart.

It is somewhat like the enthusiasm of our pro-German fellow citizens who had a change of tongue immediately after our entrance into the world war. While we were glad to see these changes we were inclined to await a change of mind and still more a change of heart. The change of tongue is the easiest human transformation, then comes a change of mind and finally a change of heart. The enthusiasm coming from the heart of the teacher is the only one which is apt to reach the heart of the student, and if your heart is in your subject you will want to know more about it.

While the summer sessions of our universities offer important facilities for the scientific development of our teachers there are other facilities which are less expensive and more permanent. Among these the high-school library deserves especial emphasis. Books are the cheapest educational factors in the world and most young teachers do not buy enough books relating to their own fields of work. What is more important they do not provide enough mathematical reading matter for their students.

The number of popular mathematical books is not very large, but this number is increasing fairly rapidly, and all high-school students should have access to at least a few of them. A few books on the history of mathematics, on mathematical recreation and on general mathematical expositions should be in every high school library. Such mathematical journals as *School Science and Mathematics* and the *American Mathematical Monthly* should also come regularly to every such library. High school students should be frequently encouraged to read mathematical articles in the general encyclopedias.

While the books and journals to which we referred should be accessible to the students of every high school, they should especially be used by the teachers, and they afford important facilities for the scientific development of these teachers. Those interested in larger collections and more explicit references should consult "A list of mathematical books for schools and colleges," containing titles of 160 books suitable for the school or college library, which was prepared by the library committee of the Mathematical Association of America, and published in the *American Mathematical Monthly*, volume 24, 1917, page 368.

It should be emphasized that this list of 160 books is for reference and not for intensive study. One of the greatest dangers which beset those of us who are anxious to become strong mathematicians is scientific dissipation. General mathematical reading is extremely useful but the backbone of the equipment of the mathematician is a profound knowledge of a few subjects, and the mastery of a comparatively small number of books. In fact, I believe that if a man would secure a thorough knowledge of certain nine mathematical books beyond a first course in elementary calculus he would be much better informed than the average candidate for the Ph.D. degree.

The mastery of nine volumes does not appear to be an insurmountable barrier between many young teachers of mathematics and the important goal of holding a place in the ranks of the real mathematicians of our land. I take it that there are many here whose views are in accord with the following words of Bacon, printed for years on the covers of the *Mathematical Gazette*: "I hold every man a debtor to his profession, from the which as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and an ornament thereunto."

The nine mathematical books whose mastery, together with a fair amount of general mathematical reading, and a development of some of the thoughts contained in these books, would make us an ornament unto our profession could be selected with considerable latitude.

As one such selection the following may be noted: Weber, "Lehrbuch der Algebra," three volumes; Goursat, "Cours d'analyse mathématique," three volumes; Veblen and Young, "Projective Geometry," two volumes—the second by Veblen alone; Eisenhart, "Differential Geometry," one volume. Those who do not read German might substitute for the three volumes of Weber's algebra the following: Bôcher, "Introduction to Higher Algebra"; Miller, Blichfeldt and Dickson, "Finite Groups"; Ried, "Theory of Algebraic Numbers." Fortunately the first two volumes of Goursat's "Cours" were translated into English by members of the mathematical department of your state university.

It may be noted that this list of nine volumes contains three volumes on each of the three broad fields of mathematics—algebra, analysis and geometry. Moreover, the mastery of these nine volumes would usually be attended by considerable reference work since some subjects are treated therein too concisely for the average student. Unfortunately there exists at present no good mathematical dictionary in any language. It is to be hoped that the Mathematical Association of America will soon remedy this great drawback, especially for the *private* study of mathematics, and it is interesting to note that the chairman of its committee having this matter under consideration belongs to your own state university.

Those who read French and German can not be too strongly advised to provide themselves with the published parts<sup>4</sup> of the large mathematical encyclopedia, whose completion has been so much delayed by the world war. The French edition of this work is especially complete, as far as it has been published, and our chief objection to the list of 160 library books noted above is that it makes no mention of this superior work of reference. Almost

equally reprehensible seems to be the omission of the very useful Volume I, "Subject, Index, Pure Mathematics," Royal Society of London Catalogue of Scientific Papers. Every student should have an opportunity to determine the limits of our present knowledge along particular lines which may interest him.

While the careful study of nine such volumes as were noted above would serve as a kind of admission card to the circle of pure mathematicians it is necessary to emphasize the fact that high standing in this circle would imply various other attainments. One of the foremost of these is a comprehensive knowledge of the literature along at least one important line of mathematical work. Such a knowledge could scarcely be acquired without using French, German and Italian literature. Hence a reading knowledge of these languages, especially the first two, is very important for the prospective mathematician. During the last two or three centuries the French have contributed more than any other nation towards the advancement of mathematics.

We have thus far failed to mention what may appear to many as the foremost qualification for a high position in the circle of mathematicians; viz., research ability of high order. It is true that the highest mathematical honors are usually reserved for those who possess this ability in a high degree in addition to the attainments to which we referred. It is, however, equally true that the highest research is usually spontaneous and takes care of itself provided the proper foundations have been laid and the necessary enthusiasm is present.

It is difficult to see how a man with high mathematical attainments and deep mathematical interest can help doing research work. It is the most charming occupation in the world even when the results appear unworthy of publication. When results are reached which seem to be of permanent value and to serve as rays of light to all future generations the investigator naturally experiences feelings of delight that enrich his inner life as few things do.

The view that all mankind has equal mathematical opportunity in this world is not

<sup>4</sup> This publication is not as far advanced as one would naturally infer from a reference thereto recently made by the retiring chairman of the Chicago Section of the American Mathematical Society on the opening page of an address published in volume 25 of its *Bulletin*.

strictly in accord with facts, but it is becoming more and more nearly true. A little more than three and a half centuries ago Robert Recorde, author of the first book in English dealing with algebra, remarked that "My fortune is not so good to have quite tyme to teache." Notwithstanding his valuable services to education he was compelled to spend the last days of his life in prison on account of his debts.

Some of our modern teachers still feel that their fortune is not so good as to give them quiet time to study, and hence they are using their spare time to add to their financial incomes. It is very unfortunate that the so-called "Tangible Rewards of Teaching"<sup>5</sup> are still so meager, but these rewards have steadily increased, especially during recent years. In a large number of cases they are now sufficient to permit complete devotion to the duties of the position and the necessary study for self-development. According to the report mentioned above, page 318, there was at least one school in this state about six years ago which paid its teachers less than fifty cents a day. It is to be hoped that such conditions do not exist to-day.

The alleviation of the mathematics teachers position is, however, more largely due to the improvement in general library facilities and the maintenance of good mathematical periodicals than to improvements in salaries. It is interesting to note that our leading mathematical journal for teachers of the college grade was started in this state, and was maintained for eighteen years (1894-1912) mainly through the sacrifices of one of your college professors. In 1916 it became the official organ of the Mathematical Association of America.

Such periodicals have done much towards establishing closer contact between mathematicians, and are thus giving to people everywhere a large number of the advantages formerly enjoyed only by those living near the great centers of mathematical activity. They

<sup>5</sup> A bulletin relating to teachers' salaries was published under this title by the U. S. Bureau of Education as *Bulletin*, 1914, No. 16.

have extended the mathematical advantages of Paris to the whole world. It is still too early to comprehend fully the marvelous mathematical transformation due to the advantages of mathematical journals of various grades. This transformation has been gradual and hence it aroused little comment, but it has largely annihilated distances from mathematical centers, and mathematical research of high order may reasonably be expected to become more and more cosmopolitan.

In recent years a new and important opportunity for service has come to the high school teachers of mathematics. Public libraries have increased in a most encouraging way, but useful mathematical literature is frequently very inadequately represented therein. Teachers of mathematics everywhere should help to correct this situation. They should not only supply those in charge with lists of most suitable mathematical books and journals but they should also encourage their own students to use the mathematical facilities offered by these libraries. If I could encourage the teachers of this state to make a strong effort to have mathematical literature properly represented in their local public libraries I should feel amply repaid for coming to this meeting.

Few students can read such an elementary book as "Philosophy and Fun of Algebra," by Mary E. Boole, without getting new light as regards the real meaning of elementary algebra. The student of elementary geometry will not only take great delight in reading such books as E. A. Abbott's "Flatland," but he will also acquire from it new and important notions as regards the nature of geometric dimensions. Mathematical clubs show that general mathematical questions attract many of our ablest young students and it seems reasonable to suppose that this will always remain true.

It is one of the mathematics teacher's great privileges to help to direct the thought of the younger generation towards a subject of sustaining intellectual interest. One of the interesting experiences of my own student life in Paris was to see two gentlemen beyond the age of sixty follow regularly a course of

lectures given at the Sorbonne by E. Picard. Mathematics is not only for the young and those who make a living therefrom, but its study leads to an intellectual penetration with unlimited room for growth. Our interest in this subject naturally grows with our knowledge thereof and the former is apt to grow much more rapidly than the latter.

In view of these facts it seems to me that all the larger city libraries should contain a considerable collection of modern mathematical works, including current parts of the best modern mathematical reference work, viz., "Encyclopédie des Sciences Mathématiques," so that new parts of this important work may become available soon after their publication. High school teachers of mathematics can render great assistance in this direction by familiarizing themselves with suitable mathematical collections and the needs of their local libraries, and suggesting improvements to the proper authorities.

Above all let us try to instil in our students a desire for more mathematical knowledge, and encourage them to utilize the facilities of local libraries along mathematical lines. Our large general dictionaries and encyclopedias contain much that can be used to advantage during mathematical recitation periods. It is scarcely necessary to say that such outside contact should not take the place of penetration into the subject in hand, but this penetration is more likely to become attractive if broad contact is kept in mind.

It should be noted that many of our best general works of reference are weak along mathematical lines. As an illustration we may note an entirely senseless definition of regular group appearing under the word *group* in the 1917 edition of the "New Standard Dictionary." This definition is as follows: "a transitive group whose order is the same as that of the letter on which it is made." Such weaknesses are, however, not always harmful to the young student since they may serve to promote the important attitude of mind of not accepting statements without study and verification. As another instance

of an unreasonable statement which appeared on the first page of a recent publication of the Department of Commerce, U. S. Coast and Geodetic Survey, No. 92, 1918, we cite the following: "It was his regular custom to spend 17 hours per day in study and writing." An almost equivalent statement appears under the name of J. H. Lambert in the ninth edition of the "Encyclopedia Britannica," but fortunately it is not found in the later edition.

As mathematics teachers, and perhaps as teachers in general, our attitude towards salaries is often inconsistent. In choosing this profession we practically say that we are more interested in intellectual matters than in the making of money. On the other hand, many of our members sacrifice intellectual opportunities for a little increase in salary. Positions which offer a reasonable income together with sufficient time and proper facilities for study should not be abandoned in favor of those offering poorer facilities for intellectual growth but a little more salary. School officials should be impressed by the fact that their teachers appreciate advantages for development and that the best teachers can be secured and held only by furnishing advantages for their development, especially in the form of good library facilities.

The great war for justice and democracy should tend to dignify our high calling since it directs so forcibly attention to the facts that it is sometimes necessary to make great sacrifices for the opportunities for higher development and the rights of nations and of individuals do not depend upon their sizes. We as teachers should be especially impressed by the fact that curtailments of rights must be based on other considerations. With the improvement in world ideals as a result of this war there should come a keener appreciation of thorough preparation for the various duties of life. The appointment of an athlete to a chemical position in Washington for which he was wholly unprepared should be regarded as close to treason even if it may have been due to the ignorance of politicians. Thorough preparation for our various duties should be

our motto as teachers and our own practise should convince the world of our sincerity.

We have thus far considered only the existing means for the scientific improvements of mathematics teachers. It may be desirable to consider also possible new means, for our science is one of infinite progress and hence we naturally look for new things. Possibly the new means for scientific development which I shall outline briefly will appear to you as too idealistic, but high ideals are essential for great progress. Hence I venture to propose that high school teachers should be required to give evidence at the end of every seventh year, until they are forty years old, of having made during the preceding seven years scientific progress equivalent to at least one year of university work.

In fact, this might commonly be in the form of a sabbatical year spent in study at some university. In special cases it might be in the form of attendance at summer sessions, or the publication of scientific work. In all cases it should be understood that the proper authorities would go over the records carefully every seventh year and would insist on such progress as a necessary condition for re-appointment. If the young teacher does not grow scientifically at least at the rate of one seventh of the normal growth of the university student he does not possess the type of mind that inspires his pupils properly.

While our young university instructors are not formally subjected to such a rule they are practically subject to a more severe scientific test in our better universities by means of a considerable series of grades, such as instructor, associate, assistant professor, associate professor, professor. In the better institutions each higher grade normally implies scientific attainments which are superior to those required for the next lower grade. It is, of course, difficult to enforce high standards in these times of scarcity of teachers, but with the return of peace we may naturally look for greater competition and higher standards.

To meet these higher standards it is not sufficient that we learn more mathematical

facts. Mathematical growth is not based so much on the number of facts as on the kind of facts. The facts must be general and far reaching. A formula involving a parameter is more general than a large logarithmic table because the former contains potentially an infinite number of special values while the latter represents only a finite number of such values. It is, however, necessary to exercise care in regard to the use of the word general in mathematics, for, what is often called general is really very special.

If one established theorem includes another it is evidently proper to speak of the former as the more general, but if one undeveloped theory embraces another it is not so clear that the former should always be regarded the more general. It may be that the generality of the principles underlying this theory is too great to permit of much progress. A theory ought to be regarded as general in proportion to its possible development and not in proportion to the generality of the definitions underlying it.

It is evident that such a use of the word general is attended by great difficulties, but it is hard to see how this word can maintain its position of respect in the mathematical literature unless we do make an effort to restrict its use to the potentially larger things. My thought may become clearer if I note the fact that the most general definition of the term group is too broad to serve as the basis of a theory. The most general group theory is therefore of zero extent and will probably always be of this extent. There is a type of definitions which give rise to the most general theory, but it is practically impossible to fix the limitations imposed by such definitions.

As an instance of a tendency to generalize unduly for the pedagogical purposes in elementary mathematics we may refer to one of the oldest among the somewhat complicated mathematical formulas, viz., the *Heron formula* expressing the area of a triangle in terms of its three sides. This formula is found in the majority of our text-books on trigonometry but it is questionable whether it can be regarded as a useful formula for the ordinary



student of trigonometry. It seems easier to solve such a triangle by dividing it into two right triangles and I understand this method is commonly pursued by the engineer. The love for generalization on the part of the teacher seems to have led him in this case to commit a serious pedagogical blunder.

In closing, I desire to urge you to do your own thinking and not to allow yourself to waste energies on the many modern fads appearing under the high sounding term of reform. The very rapid modern transformations have made us unduly vulnerable to the darts of the faddist whose audacity has outstripped that of the mine and oil promoters of the last few decades. A few mines and oil wells have paid handsomely but most of those which have been advertised extensively proved to be disastrous to the too credulous investor. A similar fate has come to those who are too credulous about educational reforms, whether they appear in the form of the function rattle popularized by F. Klein, vocational training, transfer of training, ability tests, or simply the emphasis on methods above knowledge.

As a result of the many wildcat propositions the universities used to avoid pedagogical investments altogether and they used to be fearless in warning the public against investing their hard-earned money in this way. During recent years, however, our American universities have abandoned this policy, under the leadership of Columbia, and have invested heavily in this line of securities. At first they selected the best class only but recently they seem also to invest heavily, again under the leadership of our largest university, in the more doubtful class. This is done even in the graduate schools.

Hence the public has become more and more unwary, and wildcat pedagogical promotions are thriving as never before. The richness of a few reputable pedagogical mines has served to inspire hope as regards others whose only asset is proximity to the former. Hence the grave need of caution at the present time. The educational public would seem to need some public educational commissions similar

to those recently inaugurated along financial lines to protect the ever too gullible public. The scientific development securities to which I directed your attention above do not promise the largest returns but they have withstood the severest test of the ages and hence they should be regarded as the soundest of all intellectual investments. Our students need to be trained to enjoy ideals as well as to utilize the real. Mathematics is the ideal science and there is more moving than improving in reforms.

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#### BANDED STRUCTURES OF THE AD- IRONACK SYENITE-GRANITE SERIES

THE syenite-granite series constitutes the greatest bulk of Adirondack rock. It is younger than both the Grenville metamorphosed sedimentary series and the anorthosite, the former especially having been broken up and badly cut to pieces by the syenite-granite intrusion. In mineral composition the range is from syenite rich in microperthite, orthoclase, and hornblende or augite, together with some plagioclase; to granite rich in microperthite, quartz, orthoclase and microcline, together with some plagioclase, hornblende and biotite; to monzonitic and dioritic facies rich in plagioclase, orthoclase, pyroxene and hornblende. Medium grained rocks greatly predominate but there are many variations to fine and coarse grained and even porphyritic facies. Granulation is common, the feldspars especially being most notably crushed. In structure the syenite-granite series exhibits all sorts of variations from non-gneissoid to excessively gneissoid types, with a moderate degree of foliation prevalent. The color of the typical fresh syenite is greenish-gray, while the fresh granite varies from greenish-gray, to light gray, to light red.

In this paper the features of special interest in connection with the syenite-granite series are the comparatively sharp transitions from acidic to basic facies; from greenish-gray or gray to pink or red varieties; from coarser to